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COMPARISON OF TANK ENGAGEMENT RANGES
FROM AN OPERATIONAL FIELD TEST
TO THE JANUS(A) COMBAT MODEL

by

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Comparison of Tank Engagement Ranges from an Operational Field Test to the Janus(A) Combat Model

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ABSTRACT

The purpose of this thesis is to analyze the feasibility of accrediting the Janus(A) combat model for the post-test modeling phase of an Army concept called Model-Test-Model. Specifically, tank engagement ranges collected from an operational field test are compared to similar ranges generated by simulation of the test in the Janus(A) combat model. An automated process is developed to convert position location data from the field test into Janus(A) format so that the simulation replicates the vehicles and routes used in the test. Means and distributions of tank engagement ranges are studied. The important conclusion of this thesis is that Janus(A) generates engagement ranges longer than those observed in the operational field test. Additionally, collection of test data must be improved for Janus(A) to be accredited for engagement range analysis of field tests.

THESIS DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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I. INTRODUCTION

A. GENERAL

Comparisons between operational field tests and high resolution combat models serve a dual purpose. The operational testers can save millions of dollars due to improved planning and evaluation provided by the judicious application of the models. The modeling community can enhance and improve their models based on real world occurrences in a field test. The Army's Model-Test-Model (M-T-M) concept is the integration of operational field tests and combat models. This thesis contains a report of our effort to analyze the feasibility of accrediting the Janus(A) high resolution combat model for the post-test modeling of tank engagement ranges.

We used data from the Line Of Sight-Forward-Heavy Initial Operational Test (LOS-F-H IOT) conducted at Fort Hunter Liggett, California from April through May 1990. First, an automated process to replicate the field test vehicle routes in Janus(A) was developed. Second, the test data were analyzed to see if the data were adequate to support a comparison. Third, where appropriate, comparisons were conducted between the test data and model output. Appendix B contains a list of acronyms used in this thesis.

B. DEFINITION OF ACCREDITATION

Before an assessment of the feasibility of accrediting Janus(A) for analysis of tank engagement ranges is made, we need to define accreditation. According to a memorandum signed by Mr. Walter W. Hollis, Deputy Under Secretary of the Army (Operations Research), on October 30, 1989, accreditation is "Certification that a model is acceptable for use for a specific type(s) of application(s)." [Ref. 1] Based on this definition, the thrust of this thesis is to determine if Janus(A) is acceptable for use for the specific application of modeling tank engagements that occur at Fort Hunter Liggett during a field test. In other words, can we rely on Janus(A) to reasonably approximate tank engagement ranges that occur at Fort Hunter Liggett during a field test? Validation is "The process of determining that a model is an accurate representation of the intended real-world entity from the perspective of the intended use of the model." [Ref. 1] Validation of Janus(A) is beyond the scope of this thesis. However, our work to accredit Janus(A) supports the Army goal of validating Janus(A).

C. MODEL-TEST-MODEL (M-T-M) CONCEPT

Although the M-T-M concept has been used in the Army, there is no formal Army publication that clearly defines the concept. US Army Training and Doctrine Command (TRADOC) at White Sands Missile Range, New Mexico and Research Analysis and Maintenance, Inc. have conducted most of the work in M-T-M. In October 1990, Mr. Hollis asked TRADOC Test and Experimentation Center (TEC) at Fort Hunter Liggett, California to work to improve the M-T-M methodology [Ref. 2]. TEC's first steps were to enlist the support of TRADOC Analysis Command (Monterey) and to jointly define the concept as applied to operational testing. Their joint briefing forms the basis for our description of the M-T-M concept, and is our guiding definition of the concept [Ref. 3].

The three phases of the M-T-M concept are pre-test modeling, field test, and post-test modeling. Since the focus of this thesis is on post-test modeling, the first two phases are described only briefly.

1. Phase I (Pre-Test Modeling)

The goal in this phase is to use a model to help plan the test design, including recommending scenarios for actual use on the ground. Although this should never replace on-the-ground planning, the modeler could save many valuable hours by conducting simulations with different force sizes, scenarios, and tactics. The modeler could make recommendations for improving the test design, in terms of measures of performance relevant to the tester.

2. Phase II (Field Test)

The initial phase of a field test is usually the Force Development Test and Evaluation (FDTE). In this phase the force structure, scenarios, and tactics developed by the combat model in the pre-test modeling phase could be used on the ground in the initial field test trials. The second phase of the field test is often the Initial Operational Test (IOT). Although the tactics must be unscripted for this phase, the force structure and scenarios adopted during the pre-test modeling can be used.

3. Phase III (Post-Test Modeling)

There can be many uses of a model in this phase, but we will outline three that we consider to be the most significant.

a. Compare

The model is set-up to replicate a specific field test trial. We explain a process to do this for the Janus(A) combat model in Chapter III. The modeler runs the model and specific measures of performance, such as engagement ranges, are collected. The tester and modeler compare both sets of outputs. The results of this analysis lead to the next stage.

b. Improve

(1) Model. If the results from the model do not agree with the results from the test, the modeler should take a hard look at the way the model attempts to replicate the test. There may be problems with the algorithms the model uses. There may be an error in model input parameters, such as vehicle speed or weapon ranges. The modeler's focus should

be to adjust the model to replicate the conditions of the field test, not to tweak the model just to generate similar outputs. The modeler should make adjustments until he is satisfied that the model's input parameters mirror the test conditions. If the outputs from the test and model are still different, he should focus on the terrain database and algorithms within the model for possible improvements.

(2) Test. It may be a mistake to conclude that the model is in error just because the model and test outputs are different. Even though the tester takes great care to insure he records all measurements accurately; the inherent nature of trying to record physical occurrence on the battlefield is extremely complex. The resulting data are not without flaw. Due to a large amount of human factors and instrumentation problems, the data may be unsuitable for comparison with output from a model. If the test data are seriously flawed, the tester might attempt to reconstruct some of the data. He should review the procedures used to collect the data during the test and improve them for future trials. We should note that there are varying degrees of simulation during the field test itself. For example, TEC uses random numbers to decide whether a vehicle engaged by another vehicle is "killed". If we were to compare the number of kills between the test and Janus(A), we should be aware that we are comparing two simulations. Additionally, due to the factors

described above, most of the test measures of effectiveness have large variances. These large variances may lead the analyst into accepting null hypotheses of no difference with a very low degree of power.

c. Expand

If the outputs from the model and test are similar, it may be feasible to accredit the model for a specific application. It may also be feasible to extrapolate the test evaluation by running the model with force structures and scenarios that could not be finished during the field test due to resource or testing constraints. Extrapolation of test results becomes less reliable the greater the changes to the force structure and scenarios.

D. MODELING TANK ENGAGEMENTS

1. Dependency of Multiple Engagements

We define a multiple engagement as the tank firing at the same target within a specified time interval. This time interval is defined in subsection two. We have observed that ranges in a multiple engagement are related. The cause of this dependence can be attributed to the spatial relationship between the firer and the target; both the firer and target do not move very far during a multiple engagement. The ranges in a multiple engagement are thus statistically dependent. We show statistical evidence of this dependence in Chapter II.

We model the times between rounds in a multiple engagement and call them the inter-fire times.

2. Inter-Fire Time (IFT)

The tank engagement process is extremely complex. The following model is a simplification of this process to help define the inter-fire time (IFT).

As a tank traverses the battlefield, the tank commander is searching for targets. Once he identifies a target, he lays the gun tube onto the gunner's sight picture (lay time). The gunner aims at the target by placing the crosshairs of the sight onto the target (aim time). The gunner fires a round at the target. Time of flight (TOF) is the time it takes for the round to reach the target area. The tank commander then decides if the target was destroyed (assess time). For subsequent rounds fired at the same target, the gunner aims at the target while the loader reloads the gun. The equation

$$IFT = \max(AIM, RELOAD) + TOF + ASSESS$$

defines the time between firings in a multiple engagement. For subsequent rounds in a multiple engagement, lay time is zero because we assume the gunner already has the target in his sight picture. The IFT includes the maximum of aim and reload time because these two events occur simultaneously on subsequent engagements.

3. First Range of Engagement (FRE)

The first range of engagement (FRE) is the initial range at which the gunner shoots at a target in a multiple engagement, or the only range in a singular engagement. Figure 1 summarizes the engagement process. We conduct our statistical analysis with the FRE's rather than all ranges. By considering only the FRE's, we are removing a source of dependence between engagement ranges. We do not claim that our samples of FRE's are completely independent, but we have a better case for using parametric and non-parametric statistical tests in analyses of these ranges. Due to problems with the test data outlined in Chapter II, we have narrowed the scope of analysis to tank FRE's.

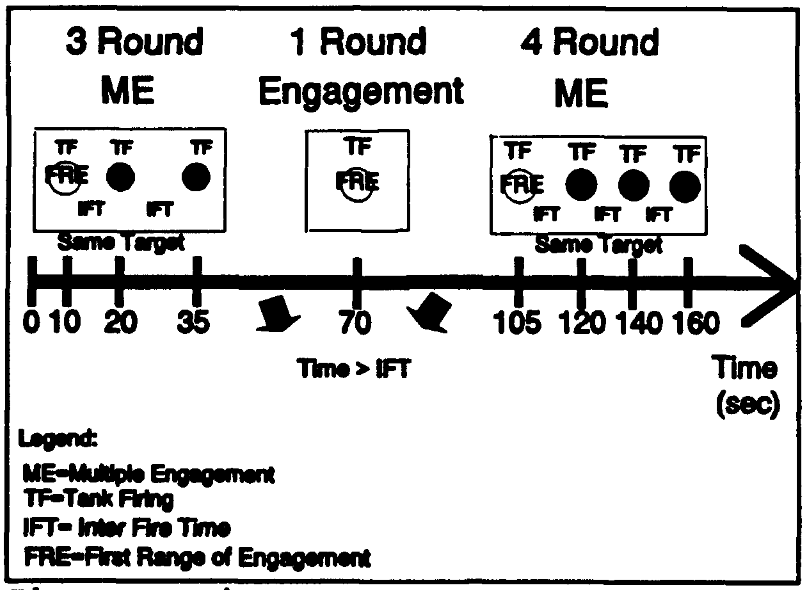

Figure 1 Diagram of Engagement Process

II. OPERATIONAL FIELD TEST

A. BACKGROUND

The Line-of-Sight Forward Heavy (LOS-F-H) is an air defense system armed with surface-to-air missiles mounted on a modified Bradley Fighting Vehicle chassis. The mission of the LOS-F-H is to defend Army heavy divisions against air attack. The purpose of the LOS-F-H IOT was to determine the operational effectiveness of a LOS-F-H platoon to accomplish its mission. TEC conducted the test at Fort Hunter Liggett, California from April 9 to May 23, 1990. The test consisted of 50 trials. Each trial, approximately one hour in length, was a force-on-force battle between instrumented Blue and Red mechanized forces of approximately battalion strength. The blue mechanized forces consisted of four LOS-F-H vehicles, 14 Abram Main Battle Tanks (M1A1), and 15 Cavalry Fighting Vehicles (CFV). The red mechanized forces consisted of 14 Future Soviet Tanks (FST) and 10 armored personnel carriers (BMP). The M60A3 main battle tank and the M113 armored personnel carrier were surrogates for the FST and BMP, respectively. In addition to the ground forces, there were various types of helicopters and aircraft on both sides. For more information on the field test see [Ref. 4].

B. TEST DATA

1. Trial Selection

The test consisted of 50 trials conducted in four scenarios. The blue force mission was either defense facing North, defense facing South, offense facing North, or offense facing South. The red force conducted the opposite mission accordingly.

An analysis of all 50 trials is beyond the scope of this thesis. To minimize the effects of systematically varied conditions on engagement ranges, six trials that occurred under the same conditions, shown in Table I, were selected.

Table I TRIALS SELECTED

Trials Selected L099B,L100B,L112B,L122B,L123B,L125B	
Factor	Condition
Light	Day
Blue Mission	Defense
Blue Orientation	North
Chemical Equip.	None
Smoke	None

2. Data Collection

TEC provided two types of data, position location (PLS) and battle (BTL) files, for each of the six trials selected. The PLS file contained a record of each vehicle's location for every second during the trial. The PLS file was used to create the vehicle routes in Janus(A). This procedure is described in Chapter III. The BTL file contained a record of each engagement between vehicles, including the firer, target, and associated engagement range, if available. These data were compared with the output from Janus(A).

3. Data Limitations

a. Position Location Errors

There are errors associated with position location data. These errors have an impact on vehicle routes and engagement ranges. If the position location is inaccurately recorded, the recorded vehicle route could be quite different from the actual. Additionally, engagement ranges are calculated from the position location data using the formula

$$Range=\sqrt{(X_{firer}-X_{target})^2+(Y_{firer}-Y_{target})^2}$$

where X and Y are the coordinates of the firer and target when the firer pulls the trigger. If the position location is inaccurate at the time of an engagement, the engagement range could be inaccurate. The range measuring system (RMS) at Fort Hunter Liggett records position location and engagement range data. An explanation of this system is given in [Ref. 5]. The three main errors associated with position location data are jitter, gaps, and spikes.

(1) Jitter. This is a slight error in recording vehicle location. The vehicle appears to be moving to a series of nearby points when it is stationary. This error is caused by slight errors in triangulation by the RMS at Fort Hunter Liggett.

(2) Gaps. These are losses of a vehicle's location for various reasons. The main cause is the vehicle moving into an area where its signal cannot be received by the RMS.

(3) Spikes. These are major errors in recording vehicle location. A vehicle appears to move to a location that is clearly not logical given its previous location. Inaccurate triangulation by the RMS is the main cause of this error.

b. Unknown Engagement Ranges

There are several reasons for errors in recording engagement ranges. We have described in the above paragraph the impact of inaccurate position location on engagement ranges. This section focuses on why some engagement ranges are not recorded in the data.

During the field test, technicians instrument weapons with lasers. When a gunner pulls a weapon trigger, a laser beam is sent in the direction of the aimpoint. The firer's identification is recorded even if the target is unknown. If the sensors on the target receive the laser beam, the RMS calculates the engagement range. If the laser beam is not received by the target, the RMS cannot determine the target's location; an engagement range is not calculated. Detailed reasons for these unknown engagement ranges are as follows.

(1) Missed Target. The gunner aimed incorrectly and legitimately missed the target. This error is most likely the cause of most of the unknown engagement ranges.

(2) Improper Laser Boresight. The laser and the weapon are not aiming in exactly the same direction. The gunner correctly aims at the target, but the laser beam travels in a slightly different direction and misses the target.

(3) Improper use of Sensors. The laser reaches the target, but the sensors do not register because they have not been properly emplaced or for some other reason cannot register illumination by the firer's laser.

(4) Attenuation of Laser Beam. The gunner correctly aims at the target, but the laser beam does not reach the target because it is attenuated by heat or dust.

(5) Insufficient Power Output. The gunner correctly aims at the target, but the laser does not have sufficient power to reach the target.

(6) Buffer Overload. In this case the sensors on the target receive the laser beam, but buffers that act as

temporary holding places for data become overloaded and the engagement is not sent to the main computer.

4. Sample Size Analysis

The limitations described above had a great impact on the sample size of engagement ranges. Tables II-V list the number of engagement ranges recorded in the data for each of the six trials we selected. These are the total number of engagement ranges before selecting only the FRE's.

Table II M1A1 ENGAGEMENT SUMMARY

TRIAL/ TARGET	L099B	L100B	L112B	L122B	L123B	L125B
FST	37	38	29	22	24	13
BMP	9	12	10	9	14	8
OTHER	15	8	7	0	3	0
TOTAL KNOWN RANGES	61	58	46	31	41	21
TOTAL UNKNOWN RANGES	149	17	29	48	28	42
TOTAL # ENGAG	210	75	75	79	69	63
PERCENT KNOWN RANGES	29.04	77.33	61.33	39.24	59.42	33.33

M1A1 engagement ranges have the highest percentage of known ranges for each trial. The average percentage of known ranges for all six trials is 45 percent of all shots fired.

The M1A1 ranges were compared with Janus(A) data. The FRE's were selected from the sample of known ranges. Chapter IV contains the sample sizes of FRE's used in the statistical analyses.

Table III FST ENGAGEMENT SUMMARY

TRIAL/ TARGET	L099B	L100B	L112B	L122B	L123B	L125B
M1A1	4	2	0	3	2	16
CFV	0	3	0	4	1	15
OTHER	0	7	0	3	3	5
TOTAL KNOWN RANGES	4	12	0	10	6	36
TOTAL UNKNOWN RANGES	67	15	16	75	23	89
TOTAL # ENGAG	71	27	16	85	29	125
PERCENT KNOWN RANGES	5.63	44.44	0	11.76	20.69	28.80

The average percentage of known FST engagement ranges for all six trials was 19 percent of all shots fired. With the exception of trial L125B, the sample size was less than five for each trial. This is not a good sample of the population of FST engagement ranges. Thus, we used only trial L125B to compare FST engagements to Janus(A).

Table IV CFV ENGAGEMENT SUMMARY

TRIAL/ TARGET	L099B	L100B	L112B	L122B	L123B	L125B
FST	13	21	4	7	8	50
BMP	19	155	7	39	40	167
OTHER	89	115	47	28	19	21
TOTAL KNOWN RANGES	121	291	58	74	67	238
TOTAL UNKNOWN RANGES	463	812	97	146	97	1190
TOTAL # ENGAG	584	1103	155	220	164	1428
PERCENT KNOWN RANGES	20.72	26.38	37.41	33.64	40.85	16.67

The average percentage of known engagement ranges for the CFV was 23 percent of all shots fired. Although this appears to be a reasonable number, further analysis of the known engagement ranges reveals that most of these ranges are repetitive. The gunner usually fires several rounds in succession at the same target using the 25mm chain gun. The ranges of these rounds recorded in the data are usually the same. As shown in Section five, the number of FRE's is low compared to the total number of engagements. Thus, a comparison of these ranges between the test and Janus(A) would lead to inconclusive results.

Table V BMP ENGAGEMENT SUMMARY

TRIAL/ TARGET	L099B	L100B	L112B	L122B	L123B	L125B
M1A1	0	3	1	0	2	3
CFV	13	0	0	0	0	24
OTHER	7	5	2	5	0	9
TOTAL KNOWN RANGES	20	8	3	5	2	36
TOTAL UNKNOWN RANGES	414	441	147	350	135	355
TOTAL # ENGAG	434	449	150	355	137	391
PERCENT KNOWN RANGES	4.61	1.78	2.00	1.41	1.46	9.21

The average percentage of known engagement ranges for the BMP was only four percent of all shots fired. This low number indicates the sample size is not a good representation of the population of BMP engagements. Thus, a comparison of these ranges between the test and Janus(A) was not conducted.

5. Correlation Analysis

Statistical evidence of the dependence of ranges in a multiple engagement is shown through a correlation analysis. An analysis of the M1A1 and CFV ranges yields very high correlation between the first and subsequent ranges within an Inter Fire Time (IFT) of 30 seconds.

Table VI M1A1 SAMPLE CORRELATIONS

Trial L099B Coefficient (Sample Size)			
Engagement Number	1st Range of Engagement	2nd Range of Engagement	3rd Range of Engagement
1st Range of Engagement	1.0000 (22)	.9986 (12)	1.0000 (2)
2nd Range of Engagement	.9986 (12)	1.0000 (22)	1.0000 (2)
3rd Range of Engagement	1.0000 (2)	1.0000 (2)	1.0000 (2)

The initial sample size of M1A1 versus FST engagement ranges for trial L099B was 37. Out of this number, 22 are FRE's, 12 are second ranges of engagement, two are third ranges of engagement, and one is a fourth range of engagement. The high estimated correlation coefficients shown in Table VI indicate dependence between the types of engagement ranges. Hypotheses that the coefficients are zero are rejected at a significance level of .05. Analyses of the M1A1 engagements for the remaining five trials yield similar results.

An analysis of the CFV ranges indicates the same high correlation between the first and subsequent ranges in a multiple engagement. Additionally, the sample size of CFV versus BMP engagement ranges for Trial L099B was 19. Out of this number only four are FRE's. A statistical analysis with only four data points out of a total of 584 rounds fired would lead to inconclusive results. Analyses of the CFV engagements for the remaining five trials yield similar results.

The low percentage of known engagement ranges for all vehicles except the M1A1 is caused by a combination of the limitations previously discussed. As a supplement to the RMS system, TEC mounts through-sight video on vehicles. Video data reduction techniques are then used to reconstruct engagements not captured by the RMS. Due to lack of time and resources, this technique was used only on the LOS-F-H vehicles. TEC is also working on a new system to replace the RMS. This new system, called KTOPS, uses radar to identify the impact of the round. Knowing the impact of the round will allow the engagement range to be calculated even if the round fails to hit the target. Post-trial reconstruction or the KTOPS system can be used in the future to enhance recording of engagement ranges.

III. JANUS(A) COMBAT MODEL

A. INTRODUCTION

Janus is an event driven, high resolution combat model named after the Roman god who was guardian of portals and patron of beginnings and endings. The model runs interactively or systemically. In the interactive mode, the red and blue forces appear on separate video terminals. The modeler views the battle as it occurs. He can affect the battle like a commander by changing options such as vehicle routes and speeds. In the systemic mode, the model runs without a man-in-the-loop for a specified time. Terrain is depicted with contour lines, vegetation, and cities. Graphical symbols represent one or more systems. Each system has one or more weapons. For example, a tank is a system containing a main gun and machine guns.

Janus uses the Night Vision Electro-Optical Laboratory (NVEOL) model for detection. When a system detects a target, an algorithm determines line of sight based on terrain and weather. If the system has line of sight, can range the target, has ammunition, and is not in a hold-fire status, it fires at the target. On the graphics display, a red line from the firer to the target designates a firing. The simulation resolves conflict by comparing random number draws to a probability of hit and kill database. Post-processing files allow the analyst to collect a wide range of data. For more detailed information on Janus see [Ref. 6].

B. TEST DATA CONVERSION

A challenge in converting data was to take the test position location (PLS) data from each of the six field trials and convert them into corresponding Janus scenarios. Without such a conversion it would be necessary to manually generate the six scenarios. It is possible to misread the many grid coordinates from the field test position location data or misplace them on the Janus screen. The human eye can only distinguish six digits of the ten digit grid coordinates on the screen. Additionally, it takes about six hours to place all the grid coordinates manually. An automated process reduces this time to one hour.

Modelers have converted data from the National Training Center (NTC), located in Fort Irwin California, to run in Janus. Mr. Al Kellner, a programmer from TRAC White Sands Missile Range, has written an extensive FORTRAN program, called INITNTC, to convert NTC battles into Janus format. TRAC (Monterey) uses this program to analyze NTC battles using Janus [Ref. 7]. The program takes four files of NTC data and makes the necessary Janus files. Once the Janus files are created, the model is run normally. For a more detailed explanation of the INITNTC program see [Ref. 8].

The FORTRAN program developed in this thesis, PLSTRN (Appendix A), takes the field test PLS data file and transforms it into four pseudo-NTC data files. The INITNTC program is then run using these pseudo-NTC files to create the necessary Janus files. Minor changes to the INITNTC FORTRAN code were made to accommodate differences in grid zone designators between Fort Hunter Liggett and Fort Irwin. Records of these changes are on file at TRAC-Monterey. Figure 2 contains a diagram of the conversion process.

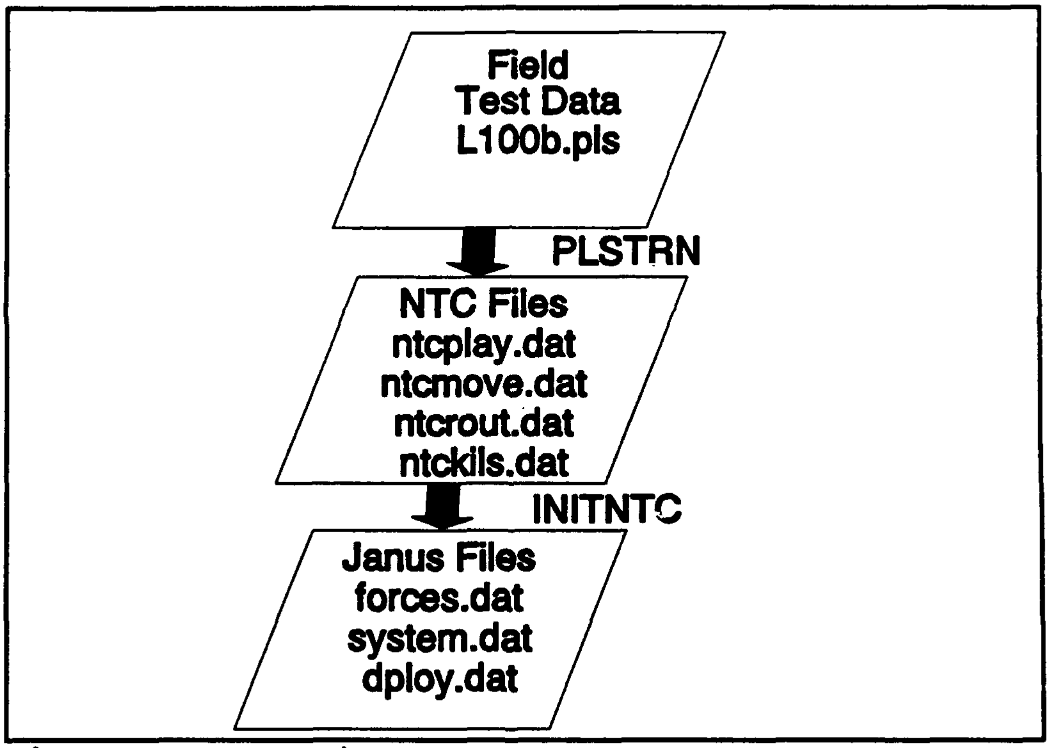

Figure 2 Conversion Process

The conversion process creates a scenario that replicates the force structure and vehicle routes of a field trial. The modeler can adjust several input parameters to further enhance the ability of the simulation to replicate a trial.

C. MODEL INPUT PARAMETERS

1. Weapon Characteristics (Ground Vehicles)

Only the weapons used during the field test were replicated in Janus. For example, during the field test, the main gun was the only weapon instrumented with lasers on each M1A1 tank. Thus, machine guns on the M1A1 tanks were not used in Janus.

Janus has a database containing hundreds of parameter values. Examples of these parameters are weapon aim time, lay time, reload time, and maximum range. Unless specifically stated in this thesis, these values were not changed as we assumed them to be correct. Subjective changes to these parameters would decrease the reliability of our results. Communication between the tester and modeler will help to identify the correct parameter values. Standardization of these values is necessary to avoid modifying them to produce desired test results.

2. Ammunition Basic Loads

During the field test, each vehicle had a specific amount and type of ammunition for each weapon, called an ammunition basic load. Testers limited the amount of laser firings for each weapon to each weapon's ammunition basic load. Ammunition basic loads used in Janus were changed to reflect the ammunition basic loads used in the field test.

3. Terrain

In Janus, terrain is simulated by a series of rectangular cells. Each cell contains the elevation at the lower left corner of the cell [Ref. 9: p. 14]. Fifty meter terrain resolution was used in the simulation because it covered the entire player maneuver area at Fort Hunter Liggett. In fifty meter terrain resolution, each side of the cell simulates fifty meters of actual terrain. A vehicle's elevation is determined by interpolation of the elevations at the four corner points of the cell in which the vehicle is located [Ref. 9: p. 15]. Elevation is important because it is used by Janus to determine line of sight between vehicles.

Roads were added to the terrain data base according to the Janus users manual using a terrain map of the maneuver area.

4. Nodes

In the Janus display, a node is a triangle connecting two line segments. The line segments represent the vehicle route. The node represents a change in direction of the vehicle route. A time can be placed on a node; a vehicle stops if it reaches a node before a time placed on a node. A vehicle continues when the simulation time is greater than the time placed on the node. Janus users place times on nodes to control the timing of the battle. INITNTC does create nodes for each vehicle route; it does not associate a time with each node. These times were placed manually for our Janus scenarios to help synchronize the battles. The data for the nodes were collected by adding an output statement to the INITNTC FORTRAN code. The computer generates a file called timenodes.dat each time INITNTC is run. This file contains the time associated with each node.

5. Weather

The test data included exact information about the visibility, temperature, and other weather conditions that existed during the field test. These conditions were replicated as closely as possible in Janus.

6. Verification

The Janus verification program checks for errors in each scenario. Failure to assign a weapon against a target is an example of an error. Verification was conducted for each scenario. All errors were corrected before the simulation was run.

D. SIMULATION RUNS

The six Janus scenarios corresponded to the six field trials selected for analysis. Each scenario was run interactively at first to insure the simulation was working properly. To determine the number of systemic runs per scenario for data collection, the criterion of determining a 95 percent confidence interval for the mean M1A1 engagement range with length 100 meters was selected. A 100 meter confidence interval is a fairly tight bound on a mean that could range from 500 to 2500 meters. A point estimate $\hat{\sigma}$ of the variance of the M1A1 engagement range was computed using data from five simulation runs of trial L100B. Solving for n the overall sample size of M1A1 engagements for a $(1-\alpha)100\%$ confidence interval of length L in each scenario, using the Central Limit Theorem, yields

$$n = \frac{z^2_{\alpha/2} \cdot \hat{\sigma}^2}{(L/2)^2}$$

or

$$n = \frac{1.96^2 \cdot 111559}{50^2} = 172 \; .$$

The average number of engagements per run was 18. To obtain a sample size of 172 engagements, the simulation would have to be run 172/18=9.55, or approximately 10 times. Thus, each of the six scenarios were run 10 times for a grand total of 60 simulation runs.

E. DATA COLLECTION

The Janus Analyst Work Station (JAWS) direct fire file was used to collect the engagement ranges. This flat ASCII file is generated from the main menu after a simulation run. A FORTRAN program computed the ranges from the X and Y location of the vehicles at the time of the engagement using the equation described on page 11. A second FORTRAN program computed the first range of engagements (FRE's) using an Inter-Fire Time (IFT) of 30 seconds. This inter-fire time was based on the values of aim time, reload time, and time of flight in the Janus database.

IV. COMPARISON OF FIRST RANGE OF ENGAGEMENTS (FRE's)

A. GENERAL

The purpose of this comparison is to determine if the means and distributions of FRE's are the same for the field test and Janus. Samples from the test consisted of FRE's from trials L099B, L100B, L112B, L122B, L123B, and L125B. Samples from Janus consisted of FRE's from ten simulation runs of each of these six trials. Normality of each of the samples was checked using the Kolmogorov-Smirnov and Chi-Square Goodness of Fit tests. In general, the data are not normally distributed. Thus, mostly nonparametric methods were used in the comparison. A significance level of .05 was established before conducting sample comparisons. The statistical software, Statgraphics, was used in the analysis of engagement range data [Ref. 10].

B. ASSUMPTIONS

The following assumptions were made before conducting Two-Sample statistical tests.

1. Independence Within Each Sample

Each sample is a random sample from its respective population. The reason for analyzing FRE's instead of all engagement ranges was to improve the tenability of assuming independence within each sample.

2. Independence Between Samples

Data in each sample are independent of data from other samples. This assumption implies that the samples from the field test are independent of the samples from Janus.

C. COMPARISON OF MEANS

The Mann-Whitney test was used to test the hypothesis that the FRE means are the same between the test and Janus. The assumptions for this nonparametric test are independence within and between samples. Field test trials were compared with corresponding Janus scenarios. Also, the test FRE's were pooled across trials and compared with the pooled Janus FRE's. Table VII contains the results of the tests. The test fails to reject the hypothesis that the means are the same in three cases indicated by asterisks in Table VII. Since the p-value is less than .05 in the other 13 cases, the hypotheses that the means are the same between the test and Janus are rejected. For the three cases where the Mann-Whitney test fails to reject the null hypothesis, the power cannot be calculated. Closer analysis of these three cases was conducted using the Two-Sample t-test as an approximate data analysis procedure. This test requires the additional assumption of normality of the samples, but is generally considered to be robust with respect to this assumption. The advantage of using the t-test is that the power of the test can be calculated.

Table VII MEAN COMPARISONS

FIRERvsTGT/ TRIAL	Mann-Whitney Tests Test Sample Size/Mean; (p-value); Janus Sample Size/Mean M1 vs FST	M1 vs BMP	FST vs M1	FST vs CFV
L099B	22/1619m **(.5462) 49/1639m	8/1141m **(.1311) 16/ 559m		
L100B	26/ 641m (.0000) 203/1919m	11/ 567m (.0000) 128/1937m		
L112B	25/1415m (.0000) 72/2354m	10/1045m (.0001) 62/2277m		
L122B	15/ 282m (.0000) 56/1370m	6/ 467m (.0031) 62/ 975m		
L123B	18/ 550m (.0000) 117/2619m	12/ 852m (.0000) 63/2788m		
L125B	13/ 873m (.0354) 13/1355m	8/ 465m (.0010) 42/1400m	10/1082m **(.0869) 21/1583m	7/1132m (.0004) 181/2621m
POOLED	119/ 951m (.0000) 510/2039m	55/ 774m (.0000) 373/1858m		

** Fail to reject hypothesis that means are equal between Field Test and Janus.

For the three cases under question, the Two-Sample t-test agreed with the Mann-Whitney test. Figures 3 through 5 contain the power curves associated with the three t-tests. We wrote an A Programming Language (APL) program to calculate the data for the power curves using [Ref. 11: p. 128]. The power function in Figure 3 indicates that if the alternate hypothesis is the difference between means is 500 meters, then the probability of accepting this hypothesis when it is true is .20. If the difference is 1000 meters, the probability is .64. The power becomes high, .94, when the difference is 1500 meters. A difference of 1500 meters is very large considering the range of the tank is approximately 3000 meters. Thus, even though the Two-Sample t-test fails to reject the null hypothesis that the means are equal, the power of the test is low. Analysis of Figure 4 indicates even lower power than Figure 3. At a difference of 500, 1000, and 1500 meters, the power is .10, .31, and .65 respectively. Analysis of Figure 5 indicates low power also with values of .15, .41, and .86 for differences between means of 500, 1000, and 1500 meters, respectively. Out of 16 comparisons, in 13 we conclude that the means are different. We have shown the low degree of power associated with the three tests that conclude that the means could be the same. Overall, the means are significantly higher in Janus. Possible reasons for these differences are discussed in Section E.

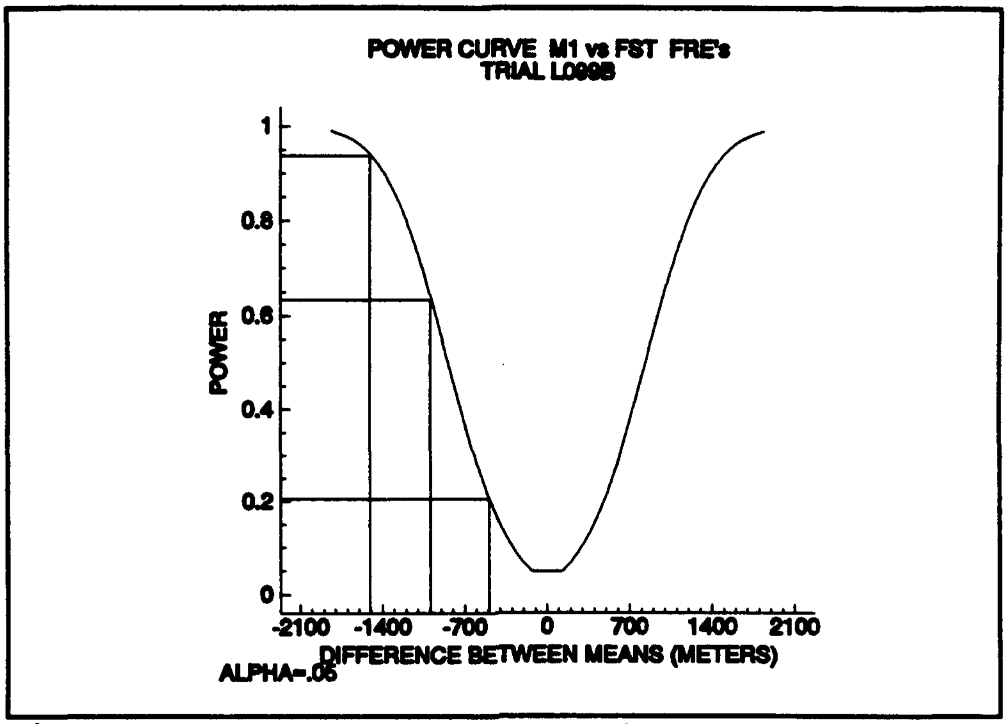

Figure 3 Power Curve (M1 vs FST)

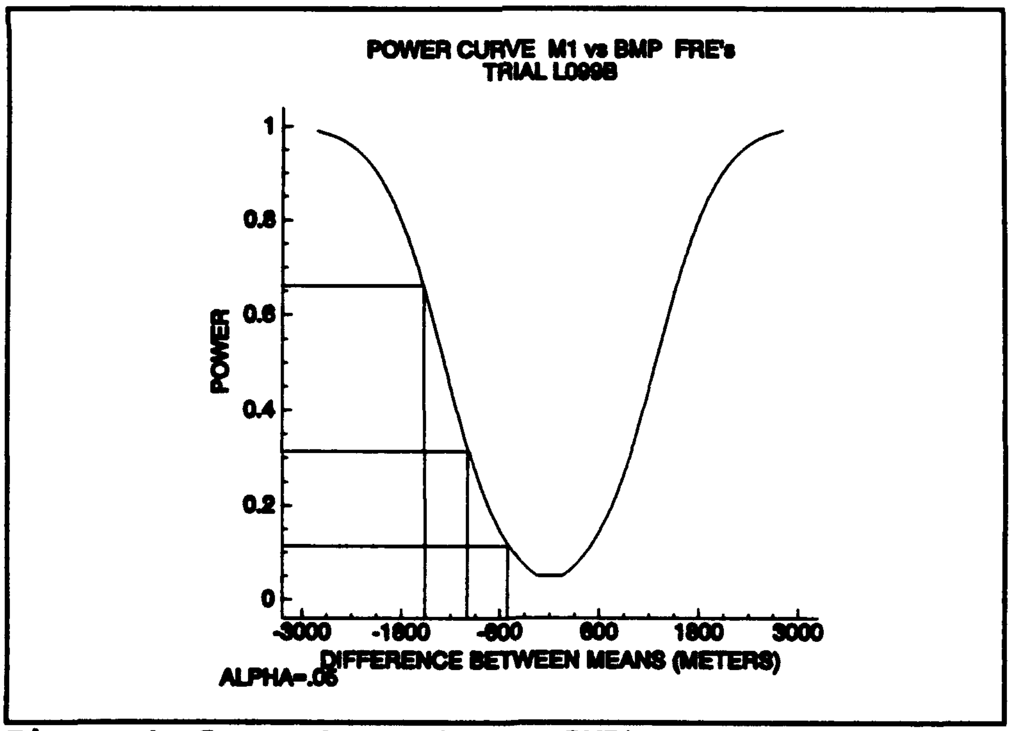

Figure 4 Power Curve (M1 vs BMP)

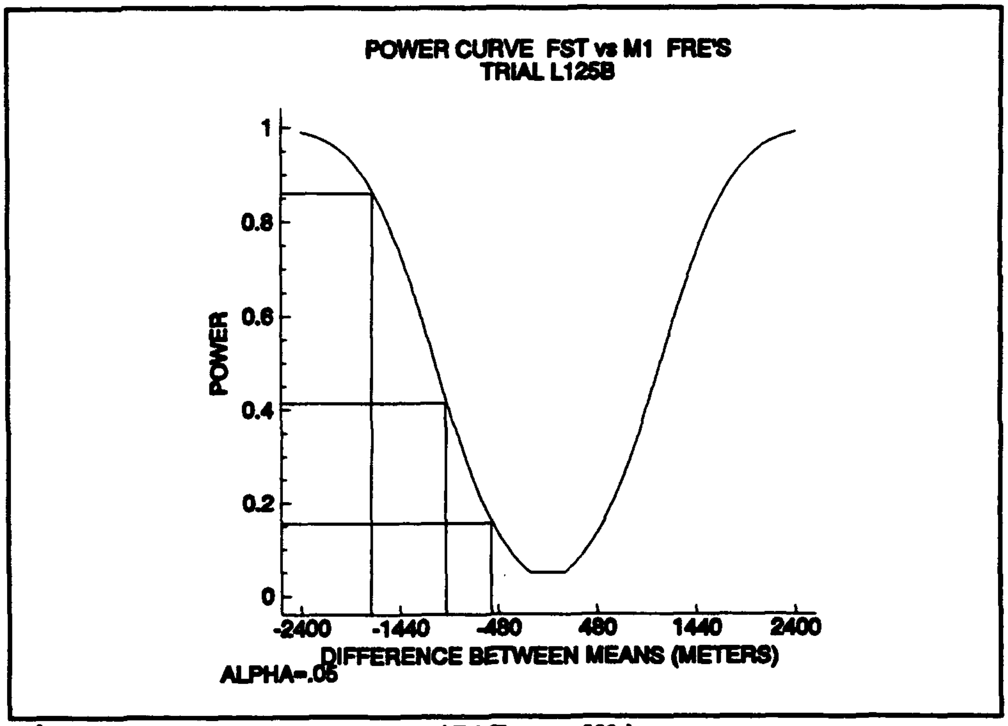

Figure 5 Power Curve (FST vs M1)

D. COMPARISON OF DISTRIBUTIONS

1. Kolmogorov-Smirnov (K-S) Tests

The Kolmogorov-Smirnov (K-S) test was used to test the hypothesis that the distributions of FRE's are the same between the test and Janus. The assumptions for this nonparametric test are independence within and between samples. Table VIII contains the results of the K-S tests. The sample sizes are the same as reported in Table VII. Out of 16 comparisons, the K-S test rejects the hypothesis that the distributions are the same in every case but one. This is strong evidence that the distributions are different.

Table VIII
DISTRIBUTION COMPARISONS

Kolmogorov-Smirnov Tests (p-value)				
FIRERvsTGT/ TRIAL	M1 vs FST	M1 vs BMP	FST vs M1	FST vs CFV
L099B	(.0375)	(.0310)		
L100B	(.0000)	(.0000)		
L112B	(.0000)	(.0000)		
L122B	(.0000)	(.0195)		
L123B	(.0000)	(.0000)		
L125B	(.0146)	(.0002)	** (.2059)	(.0019)
POOLED	(.0000)	(.0000)		

**Fail to reject hypothesis that distributions are the same between Field Test and Janus.

2. Empirical Quantile-Quantile Plots

To determine how the distributions differ, empirical quantile-quantile (Q-Q) plots were drawn.

a. Method of Construction

This plot is constructed by plotting the quantiles of one empirical distribution against another. Each sample of FRE's is ordered from lowest to highest. If the sample sizes are the same, the ordered samples are plotted against each other. Since the sample sizes are different in the data, the quantiles from the larger data were linearly interpolated onto the smaller data set [Ref. 12: p. 55]. The ordered smaller sample was plotted against the interpolated data.

b. Interpretation

The line Y=X is the reference for the empirical quantile-quantile plot. If the plot lies along the line Y=X, then the distributions are the same. If the plot has the same slope with a different intercept, then the distributions are the same with a shift in location. If the plot is a straight line with a different slope, then the variances of the distributions differ. Figures 6 and 7 contain the empirical quantile-quantile plots of the pooled data for the M1A1. The points do not lie along a straight line, but along a quadratic curve. It is clear that Janus produces longer engagement ranges than the field test for the M1A1 up to 3000 meters. Beyond 3000 meters, the ranges are longer in the field test; this is because the maximum range for the M1A1 in the Janus database is less than the maximum range for the M1A1 in the field test. In the field test, six out of the 119 M1A1 FRE's were beyond 3000 meters; none were observed beyond 3000 meters in Janus. Figure 8 contains the differences between field test and Janus quantiles plotted against the Janus quantiles. This plot shows that as the Janus ranges increase to 2500 meters, the difference between the field test and Janus ranges increase; the test ranges vary from 200 to 1500 meters shorter. Beyond 2500 meters, the differences decrease.

Figure 9 contains the empirical quantile-quantile plot for the FST versus the M1A1 in Trial L125B. The plot appears to be a straight line with slope equal to one and intercept equal to -539. Thus, the distributions appear to be the same with a change in mean. The plot shows that Janus produces ranges for the FST that are approximately 539 meters longer than the field test. It would be inappropriate to conclude that Janus produces FST ranges similar to the field test in distributional shape based on analysis of only one trial consisting of ten data points.

Overall, the K-S tests and empirical quantile-quantile plots show that the distributions of FRE's within and across trials are different between Janus and the field test. Janus does not generate engagement ranges similar in mean and distribution to the field test data.

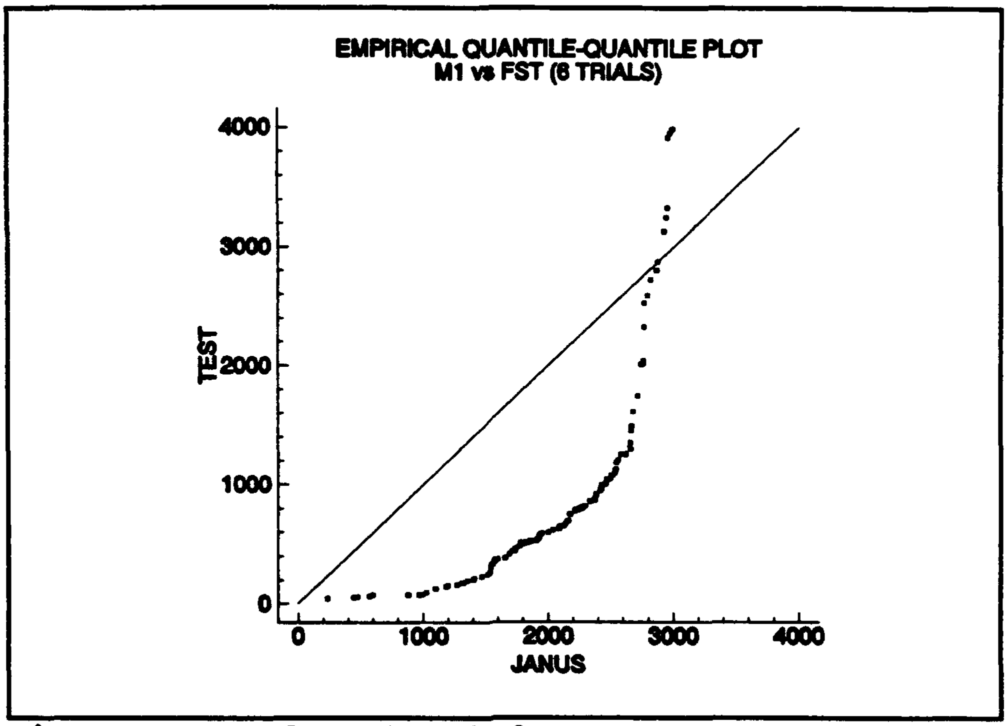

Figure 6 Q-Q Plot of pooled M1 vs FST FRE's (meters)

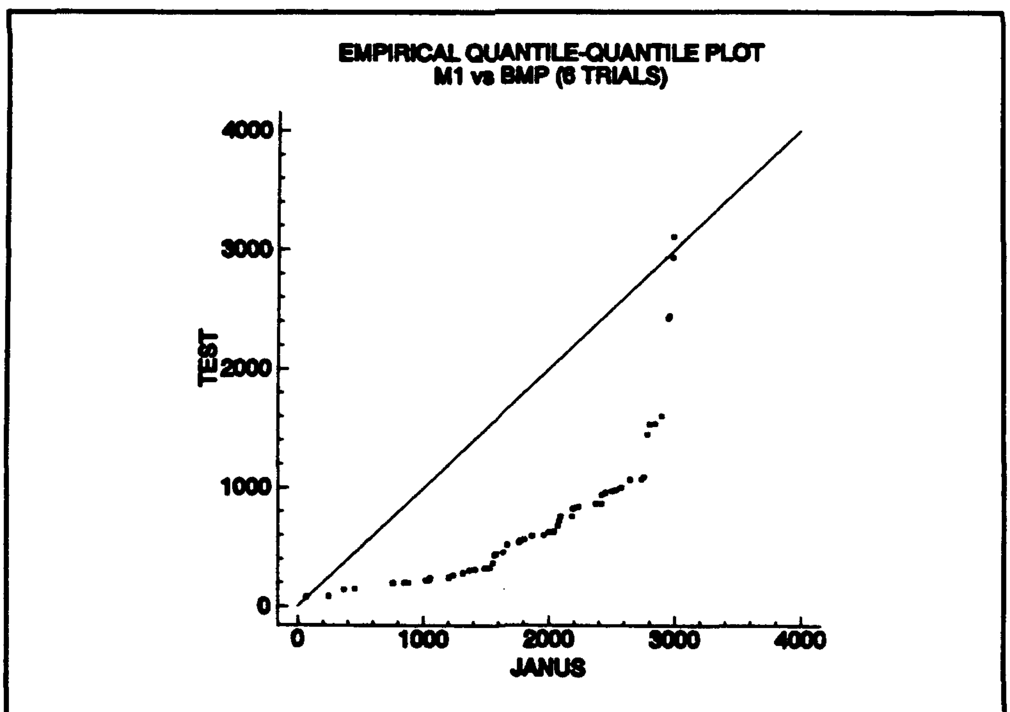

Figure 7 Q-Q Plot of pooled M1 vs BMP FRE's (meters)

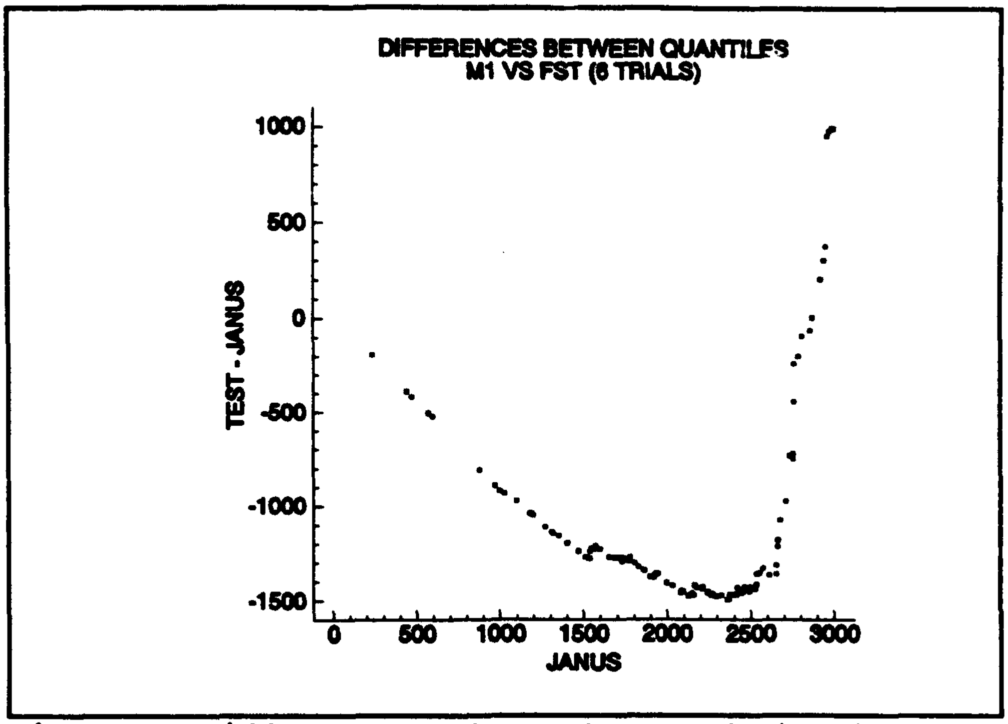

Figure 8 Differences Between Ranges (meters)

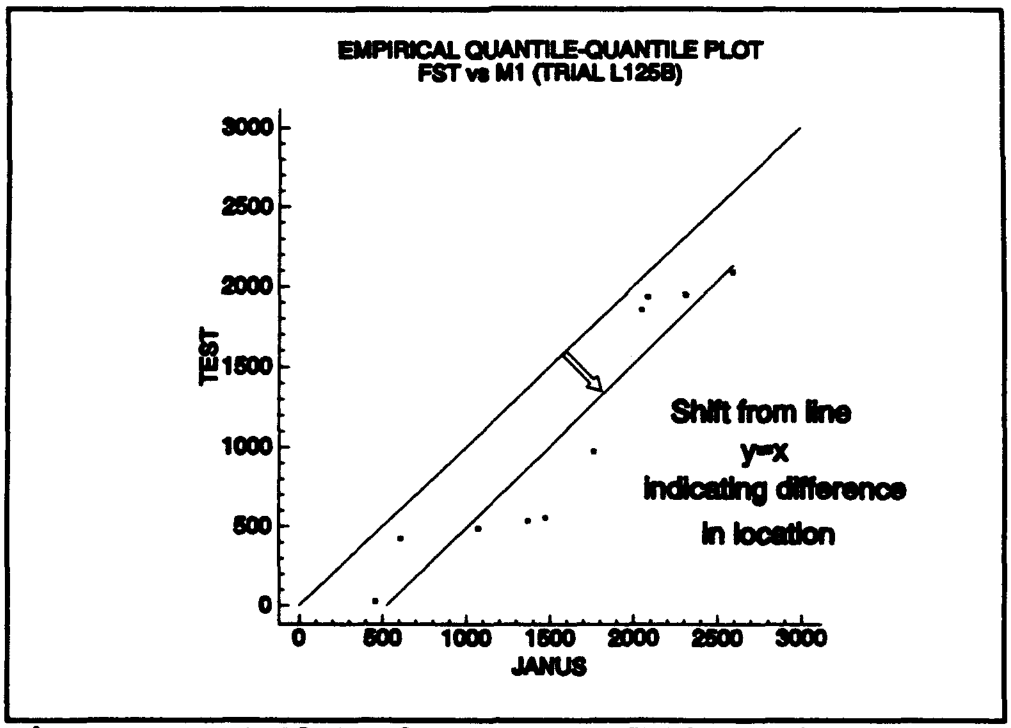

Figure 9 Q-Q Plot of FST vs M1 FRE's (meters)

E. ANALYZING THE DIFFERENCES

1. Range Versus Time

All six of the trials have Red in the offense while Blue is in the defense. The Red forces start in the North and move toward the Blue forces in the South. In general, as time increases, the engagement ranges should decrease because the opposing forces move closer to each other. Tanks remaining on high ground may get long range shots throughout the battle or blue forces positioned forward may engage early, but most of the engagement ranges should get shorter as the battle progresses. A correlation analysis of range and time for the pooled Janus and field test data revealed that range is negatively correlated with time. Since both Janus and field test data support the idea that range decreases as time increases, why do the ranges differ?

Clues about why Janus produces longer engagement ranges than the field test are found by plotting range versus time for a trial. Figures 10 and 11 are range versus time plots for trial L112B. The field test version of this trial had four blue tanks positioned North engage Red tanks ten minutes into the battle at a range of 400 to 800 meters and then withdraw to the remaining blue forces in the South. The main battle occurred at 50 minutes at a range of 1000 to 1800 meters. A blue tank positioned on high ground engaged at 4000 meters near the end of the battle.

The Janus version of this trial had the four blue tanks engage two minutes into the battle at a range 1100 to 3000 meters. The main battle occurred at 35 minutes at a range of 2300 to 2800 meters. Since the maximum range of the M1A1 in Janus is less than 4000 meters, the 4000 meter engagements observed in the field test were not possible in Janus. Janus accurately represented the flow of the battle. The only difference is that Janus engaged earlier at longer ranges.

An interview with one of the tank company commanders from the field test indicated that most of the tank engagements occurred at close range mainly because of three reasons.

The players are required to wear laser safe goggles that restrict vision to varying degrees.

The heavy amount of dust stirred-up by mechanized vehicles obscures targets.

The undulations in the terrain restrict line-of-sight beyond about 1000 meters.

The tank company commander added that players did not wait for targets to enter engagement areas before firing. Of the above reasons, only the protective goggles would not be a factor in actual combat. Even if the players were not required to wear goggles, the other two reasons are sufficient to support short range tank engagements at Fort Hunter Liggett. Janus does represent dust and terrain. The 50 meter terrain resolution used in this simulation evidently does not represent the undulations and extent of vegetation the players actually face on the ground.

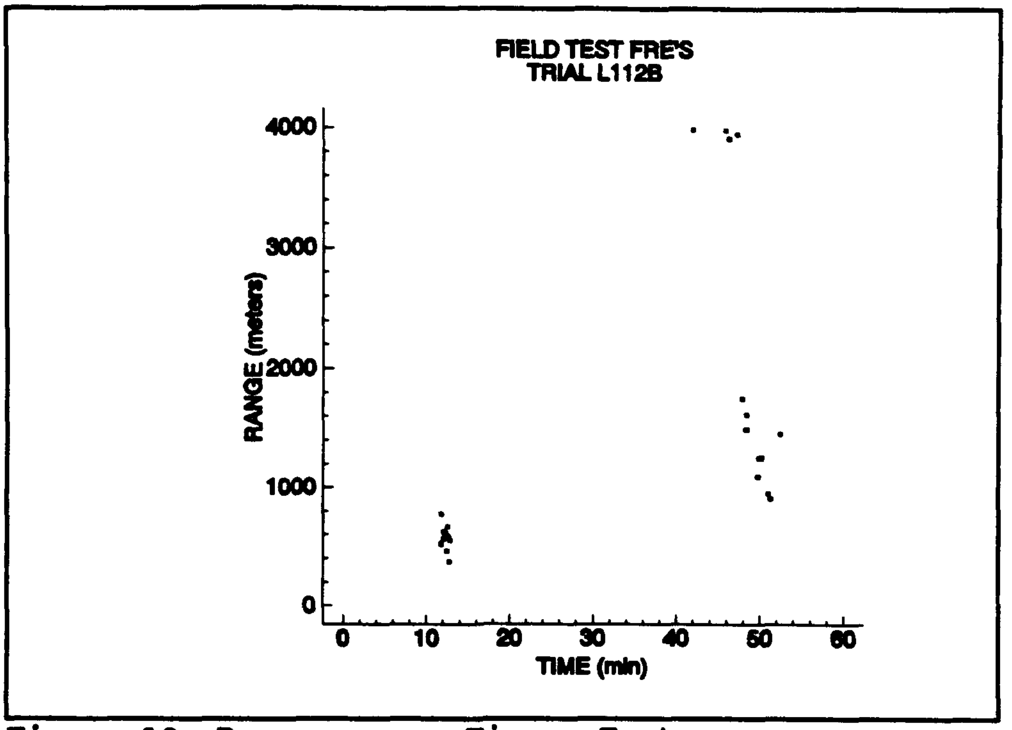

Figure 10 Range versus Time - Test

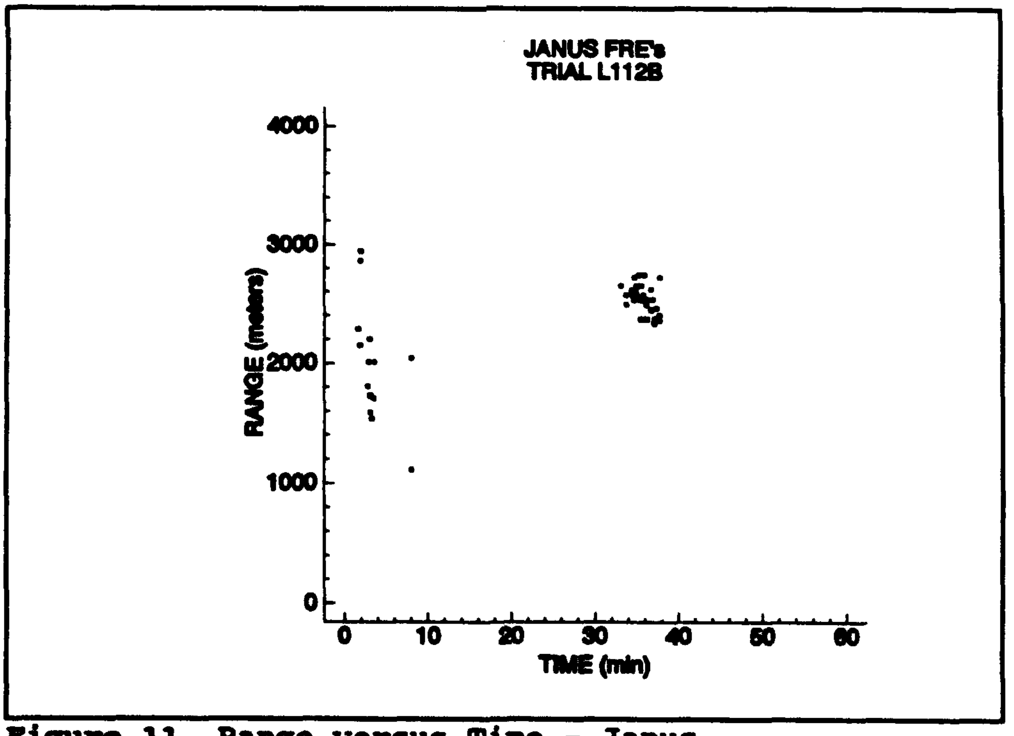

Figure 11 Range versus Time - Janus

2. Number of Rounds Fired in a Multiple Engagement

a. Field Test Data

Recall that we defined a multiple engagement as a tank firing at the same target within the inter-fire time. There is evidence in the field test data that the number of rounds a tank fires in a multiple engagement, N, is a geometric random variable with p estimated to be .7391. The geometric random variable, N, records the trial number of the first success. Each trial has the same probability of success, p. For our model, a trial is the tank firing a round, and a success occurs when the tank stops firing at the target within the inter-fire time. A success occurs when,

1. the target is hit,
2. the firer is hit, or
3. line of sight no longer exists between the firer and the target.

Thus, the probabilities that a tank fires N rounds during a multiple engagement are estimated to be,

$$\hat{P}(N=1) = .7391(1-.7391)^0 = .7391 \ ,$$

$$\hat{P}(N=2) = .7391(1-.7391)^1 = .1928 \ ,$$

$$\hat{P}(N=3) = .7391(1-.7391)^2 = .0503 \ ,$$

and

$$\hat{P}(N\geq 4) = 1- [\hat{P}(N=1) + \hat{P}(N=2) + \hat{P}(N=3)] = .0178 \ .$$

Evidence for this geometric fit was obtained using the Chi-Square Goodness of Fit test shown in Table IX with the pooled M1A1 engagement data. The estimate for the parameter, p, was obtained from

$$\bar{X}=\frac{87(1)+24(2)+6(3)+2(4)}{119}=1.3529$$

and

$$\hat{p}=\frac{1}{\bar{X}}=\frac{1}{1.3529}=.7391\ .$$

The hypothesis was not rejected because

$$P(\chi^2_2 > .06514) = .9680 > .05\ .$$

Table IX CHI-SQUARE GOODNESS OF FIT TEST

H_0: # Rounds per Multiple Engagement is Geometric

# Rounds per multiple engag	Observed	Expected	$[(O-E)^2] / E$
1	87	87.95	.01032
2	24	22.95	.04832
3	6	5.99	.00003
≥ 4	2	2.11	.00647
Total	119	119	.06514

degrees of freedom = #cells - #parameters estimated - 1 = 2

To determine a hit for each engagement during the field test, the computer compares a random number with a probability of hit contained in a database. Since the probability of hit increases as the range decreases, the high estimated probability of success, $\hat{p}$ =.7391, indicates that field test engagement ranges are short. Because loss of line of sight also results in a "success", the high probability of success also indicates that line of sight between the firer and target is frequently broken.

b. Janus Data

Analysis of the Janus data revealed that the number of rounds fired in a multiple engagement is not a geometric random variable. The estimated probability of success was lower than the field test, $\hat{p}$ =.4966, and the null hypothesis of fit to a geometric distribution was rejected with a significance of .0442. The Janus data do not fit a geometric distribution because there were several observations in the tail of the geometric distribution; the Janus data contained three multiple engagements consisting of 11, 14, and 15 rounds. Seven percent of the multiple engagements contained five or more rounds; the highest number of such rounds fired in the field test data was four. To resolve an engagement, Janus compares a random number with a probability of hit contained in a database. Since the probability of hit decreases as the range increases, the repetitive firing by

Janus indicates that tanks engage at longer ranges and that line of sight is frequent and of longer duration.

V. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSION

At this time, Janus should not be accredited for post-test modeling of ground vehicle engagements because,

1. statistically significant differences in tank engagement ranges exist between Janus and the Line Of Sight-Forward-Heavy Initial Operational Test; and

2. the test data were insufficient to support engagement range analysis of the Cavalry Fighting Vehicle or BMP.

Six of the 50 field test trials were analyzed. Janus consistently generated tank engagement ranges 200 to 1500 meters longer than those observed in the field test. In general, Janus accurately represents the flow of the battle, but engages targets earlier when the range is greater. This suggests that line of sight exists in the model when it does not exist in the field test.

B. RECOMMENDATIONS

1. Field Test

The field test data contained several engagements of unknown range. This trend was apparent in all the trials and especially noticeable with the BMP, Cavalry Fighting Vehicle, and Future Soviet Tank. Improvements in instrumentation are necessary to increase the fraction of engagements that have engagement ranges in the data.

2. Janus

Currently, the Defense Mapping Agency (DMA) prepares terrain for combat simulation models down to 12.5 meter resolution. Recommend analysis of engagement ranges in Janus using terrain resolution lower than 50 meters. This may require segmenting the battle because terrain resolution lower than 50 meters does not cover the entire playing area at Fort Hunter Liggett. If Janus continues to generate longer engagement ranges, the terrain database should be analyzed for agreement with the actual terrain.

The parameters in the Janus combat systems database should be verified by a team of testers and modelers.

The model contains a target selection algorithm that permits the firer to continue firing at the same target until the target is destroyed or moves out of line of sight. On the surface, this appears to be a reasonable model of real world engagements. However, in some cases during the simulation, the firer expends a large portion of the basic load at the same target. This continual firing does not occur in the field test. Modelers should analyze this algorithm to see if modifications are appropriate.

Janus displays great potential as an effective tool in the post-test modeling phase of the Model-Test-Model concept. Additional comparisons should be conducted to enhance both the model and field test.

APPENDIX A: FORTRAN CONVERSION PROGRAM

```
      PROGRAM PLSTRN

*     THE MAIN PROGRAM TAKES THE TEC POSITION LOCATION DATA
*     WHICH IS BY SECOND AND EXTRACTS EVERY MINUTE FOR JANUS
*     USE. JANUS CAN ONLY HANDLE 50 NODES.  EACH TRIAL IS
*     ABOUT 50 MINUTES LONG, SO POSITION LOCATION DATA FOR
*     EVERY MINUTE RESULTS IN APPROXIMATELY 50 NODES PER
*     VEHICLE.

*     THERE ARE TWO REQUIREMENTS FOR THIS PROGRAM. ONE, THE
*     POSITION LOCATION DATA FILE FROM THE FIELD TEST. TWO,
*     THE EXACT NUMBER OF VEHICLES RECORDED IN THE DATA.

      INTEGER SS, X, Y, NUMVEH
      CHARACTER PID*4,TIME*5,FILE*9

      COMMON NUMVEH

      PRINT *,'INPUT FILE (EG L112B.PLS) ? (USE APOSTROPHES)'
      READ *,FILE

      OPEN(UNIT=10,FILE=FILE,STATUS='OLD',RECL=69,
```

```
C CARRIAGECONTROL='LIST')

 PRINT*,'ENTER TOTAL # OF VEHICLES (INCL AIRCRAFT) IN
C TRIAL'
 PRINT*,'TRIAL L099B=63'
 PRINT*,'TRIAL L100B=62'
 PRINT*,'TRIAL L112B=67'
 PRINT*,'TRIAL L122B=66'
 PRINT*,'TRIAL L123B=61'
 PRINT*,'TRIAL L125B=67'

 READ*,NUMVEH
 PRINT *,'PROGRAM CONTINUING...'

 OPEN(UNIT=11,FILE='CHRONORD.DAT',STATUS='NEW'
C,FORM='FORMATTED')
 5  READ(10,10,END=30) TIME,SS,PID,X,Y
10  FORMAT(10X,A5,1X,I2,1X,A4,1X,I5,1X,I5)

    IF(SS.EQ.0) WRITE(11,20) TIME,PID,X,Y

20  FORMAT(1X,A5,':00',2X,A4,2X,I5,2X,I5)
    GO TO 5
30  CONTINUE
    CLOSE(UNIT=10)
    CLOSE(UNIT=11)
```

```
      PRINT*,'FINISHED CONVERTING PLS'
      PRINT*,'PROGRAM CONTINUING...'

      CALL FOURFILE

      END


      SUBROUTINE FOURFILE

C*****THIS SUBROUTINE CREATES FOUR FILES--
C*****(NTCMOVE999.DAT,NTCROUT999.DAT,NTCPLAY999.DAT,
C*****NTCKILS999.DAT) WHICH ARE USED BY INITNTC TO RUN JANUS.
C*****ADDITIONALLY, BADGRID999.DAT CONTAINS ALL THE GRIDS FROM
C*****THE TRIAL THAT WILL NOT FIT ON A 50X50 JANUS MAP.

      INTEGER LPN,X,Y,NTCTYPE,I,NUMVEH,J
      CHARACTERDATE*9,TIME*8,TECTYPE*2,SIDE*1,PID*3,BOGUS*64
      LOGICAL WRITEPLAY

      COMMON NUMVEH

      OPEN(UNIT=10,FILE='NTCROUT999.DAT',STATUS='NEW')
      OPEN(UNIT=11,FILE='NTCMOVE999.DAT',STATUS='NEW')
      OPEN(UNIT=36,FILE='NTCPLAY999.DAT',STATUS='NEW')
      OPEN(UNIT=37,FILE='NTCKILS999.DAT',STATUS='NEW')
```

```
C*****NTCKILS999.DAT IS A FILE WITH HEADINGS ONLY.  IT IS NOT
C*****NECESSARY TO RUN JANUS, BUT INITNTC LOOKS FOR THE FILE
C*****AND WILL TERMINATE WITHOUT IT.

      OPEN(UNIT=14,FILE='BADGRID999.DAT',STATUS='NEW')

      WRITE(14,*) 'THESE GRIDS HAVE BEEN DELETED SINCE '
      WRITE(14,*) 'THEY DO NOT FIT ON A 50X50 JANUS MAP...'
      WRITE(14,*) ' '


C*****NTCMOVE999.DAT USES CHRONORD.DAT

      OPEN(UNIT=13,FILE='CHRONORD.DAT',STATUS='OLD')
      WRITE(10,*) ' '
      WRITE(11,*) ' '
      WRITE(36,*) ' '
      WRITE(37,*) ' '
      WRITE(10,*)'routs_all table'
      WRITE(11,*)'move_all table'
      WRITE(36,*)'pdscr table'
      WRITE(37,*)'kills_all table'
      WRITE(10,*) ' '
      WRITE(11,*) ' '
      WRITE(36,*) ' '
      WRITE(37,*) ' '
```

```
      WRITE(10,1)
      WRITE(11,1)
    1 FORMAT(':time',16X,':lpn ',2X,':side',2X,':pid',3X,':',
     C'ptype',1X,':x',4X,' :y',5X,':')
      WRITE(10,2)
      WRITE(11,2)
    2 FORMAT(':-------------------:------:------:------'
     C,':------:------:------:')
      WRITE(36,33)
      WRITE(37,34)
   33 FORMAT(':lpn',3X,':pid',3X,':side',2X,':org',17X,':ptype
     C ')
   34 FORMAT(':tlpn',1X,':tpid',1X,':side',1X,':result',
     C ':time',16X,':tx',3X,':ty',3X,':flpn',2X,':fpid'
     C,2X,':fwpn',2X,':fx',3X,':fy',3X,':fy',3X,':frat  :')
      WRITE(36,*)' '
      WRITE(37,*)' '

C*****DUMMY DATE
      DATE='12 APR 90'


C*****CREATING NTCMOVE999.DAT


      LPN=0
    7 LPN=LPN+1
```

```
      IF(LPN.EQ.NUMVEH+1) LPN=1
      READ(13,20,END=40) TIME,TECTYPE,PID,X,Y

10    CONTINUE
      IF(TECTYPE.EQ.'AH') THEN
         NTCTYPE=22
         SIDE='B'
      ELSEIF(TECTYPE.EQ.'BR') THEN
         NTCTYPE=29
         SIDE='B'
      ELSEIF(TECTYPE.EQ.'FT') THEN
         NTCTYPE=1
         SIDE='B'
      ELSEIF(TECTYPE.EQ.'LO') THEN
        NTCTYPE=10
        SIDE='B'
      ELSEIF(TECTYPE.EQ.'OH') THEN
        NTCTYPE=26
        SIDE='B'
      ELSEIF(TECTYPE.EQ.'CC') THEN
        NTCTYPE=14
        SIDE='B'
      ELSEIF(TECTYPE.EQ.'AG') THEN
        NTCTYPE=25
        SIDE='B'
      ELSEIF(TECTYPE.EQ.'BM') THEN
```

```
  NTCTYPE=3
  SIDE='O'
ELSEIF(TECTYPE.EQ.'HP') THEN
  NTCTYPE=27
  SIDE='O'
ELSEIF(TECTYPE.EQ.'TT') THEN
  NTCTYPE=1
  SIDE='O'
ELSEIF(TECTYPE.EQ.'TV') THEN
  NTCTYPE=20
  SIDE='O'
ELSEIF(TECTYPE.EQ.'FF') THEN
  NTCTYPE=25
  SIDE='O'
ELSEIF(TECTYPE.EQ.'TH' ) THEN
  NTCTYPE=23
  SIDE='O'
ELSE

  PRINT*,'DO NOT HAVE A NTCTYPE MATCH FOR TECTYPE
C    ',TECTYPE
  PRINT*,'HAVE ASSIGNED IT A NTCTYPE OF 0 (ZERO) AND PUT
  PRINT*,'ON THE BLUE SIDE'
  PRINT*,'PROGRAM CONTINUING...........'
  NTCTYPE=0
  SIDE='B'
```

```
      ENDIF


      IF((X.GT.50000.AND.X.LT.65000).AND.(Y.GT.73000
     C   .AND.Y.LT.88000))  THEN
         WRITE(11,30) DATE,TIME,LPN,SIDE,PID,NTCTYPE,X,Y
      ELSE
         WRITE (14,20) TIME,TECTYPE,PID,X,Y
      ENDIF


      GO TO 7



  20  FORMAT(1X,A8,2X,A2,A3,1X,I5,2X,I5)
  30  FORMAT(': ',A9,1X,A8,':',I3,
     C,3X,':',A1,5X,':',A3,3X,':',I2
     C,4X,':',I5,' :',I5,' :')

  40  CONTINUE



      CLOSE(UNIT=11)
      CLOSE(UNIT=13)
      CLOSE(UNIT=14)

C******CREATING NTCROUT999.DAT
      OPEN(UNIT=81,FILE='NTCMOVE999.DAT',STATUS='OLD')
```

```
      I=1

95    DO 76 J=1,5
         READ(81,82) BOGUS
82    FORMAT(1X,A64)
76    CONTINUE

      WRITEPLAY=.TRUE.
83    READ(81,84,END=66) DATE,TIME,LPN,SIDE,PID,NTCTYPE,X,Y

84 FORMAT(2X,A9,1X,A8,2X,I3,4X,A1,6X,A3,4X,I2,5X,I5,2X,I5)
      IF(LPN.EQ.I) THEN
        WRITE(10,30) DATE,TIME,LPN,SIDE,PID,NTCTYPE,X,Y
        IF(WRITEPLAY) THEN
C******CREATING NTCPLAY999.DAT
          WRITE(36,85) LPN,PID,SIDE,NTCTYPE
          WRITEPLAY=.FALSE.
        ENDIF
      ENDIF
      GO TO 83
66    CLOSE(UNIT=81)
      OPEN(UNIT=81,FILE='NTCMOVE999.DAT',STATUS='OLD')

85    FORMAT(':',I3,3X,':',A3,3X,':',A1,5X,':',20X,':',I2,4X
     C ,':')
```

```
      I=I+1

      IF(I.EQ.NUMVEH+1) GO TO 99
      GO TO 95

   99 CONTINUE
      WRITE(10,2)
      WRITE(37,*)' '

      RETURN
      END
```

APPENDIX B: LIST OF ACRONYMS

BMP	Soviet Mechanized Infantry Vehicle
BTL	Battle File from field test data
CFV	Cavalry Fighting Vehicle, US Army
FDTE	Force Development Test and Evaluation
FORTRAN	Formula Translation Computer Language
FRE	First Range of Engagement
FST	Future Soviet Tank
IFT	Inter-Fire Time
INITNTC	Program to convert NTC battles to Janus format
IOT	Initial Operational Test
JAWS	Janus Analyst Workstation
LOS FH	Line Of Sight Forward Heavy Air Defense System
M1A1	US Army Abrams tank
MTM	Model Test Model
NTC	National Training Center
NVEOL	Night Vision Electro Optical Laboratory
PLS	Position Location System
RMS	Range Measuring System
TEC	TEXCOM Experimentation Center
TEXCOM	Testing and Experimentation Command
TOF	Time Of Flight
TRAC	Training and Doctrine Analysis Command

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